

Additions to Podostemaceae Subfamily Podostemoideae of Laos

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Based on recent collections, *Hydrobryum luangnamtaense* (sp. nov.) and *Thawatchaia laotica* (sp. nov.) endemic to Laos, and *H. japonicum*, *Polypleurum longistylusum* and *Paracladopus chanthaburiensis*, all subfamily Podostemoideae, are reported as new to the flora of Laos. As a result, 20 species in six genera of Podostemoideae are known to occur in Laos. In total, Laos harbors 35 species in nine genera of the family Podostemaceae and is the second most species-rich country in Southeast Asia. A key to the genera and a key to the species of Podostemoideae in Laos is updated.

Key words: *Hydrobryum*, Laos, *Paracladopus*, Podostemaceae, Podostemoideae, *Polypleurum*, *Thawatchaia*

Podostemaceae (river-weeds) are aquatic haptophytes adapted to rapids and waterfalls in the tropics and subtropics. Members of the family grow submerged in violent current in the rainy season, then flower and fruit in the air in the dry season. The Podostemaceae comprise three subfamilies, of which Podostemoideae and Tristichoideae occur in Asia (Cook & Rutishauser 2007). In our studies using recent collections from Laos, we recorded 15 species in five genera of Podostemoideae (Koi & Kato 2012) and 15 species in three genera of Tristichoideae (Koi & Kato 2015). The numbers of species and genera in the family are about four times and two times as large as previously reported, respectively (Cusset 1973a, 1973b, 1992, Kato & Fukuoka 2002). Additional specimens were recently collected, mostly from northern Laos, which has been poorly explored, as well as from southern Laos. Those collections add five species in four genera, of which one genus is new to the Podostemoideae of Laos; two species are new to science. The specimens are deposited in the Herbarium (TNS), Depart-

ment of Botany, National Museum of Nature and Science (Tsukuba) and the National Herbarium of Laos (HNL).

Description of New Species and New Records

***Thawatchaia laotica* Koi & M. Kato, sp. nov. — Fig. 1**

Typus. Northern Laos. Luang Namtha Province: stream along Route 17B, between Ban Houay Mo and Ban Kang Kao, 657 m alt., 21°00'57.9" N, 100°56'53.0" E, 13 Jan. 2011, S. Koi, N. Katayama & T. Wongprasert LK-307 (holotype TNS!, isotype HNL!).

Root crustose, irregularly lobed, 0.3–0.4 mm thick (reproductive part). Flowering shoots bearing solitary terminal flowers, scattered on dorsal surface of root, appressed to root surface, 3–4 mm long (from base to tip of uppermost bract). Flowers strongly oblique; bracts thick, 2-ranked, (4–)6–10, markedly asymmetrically trilobed with

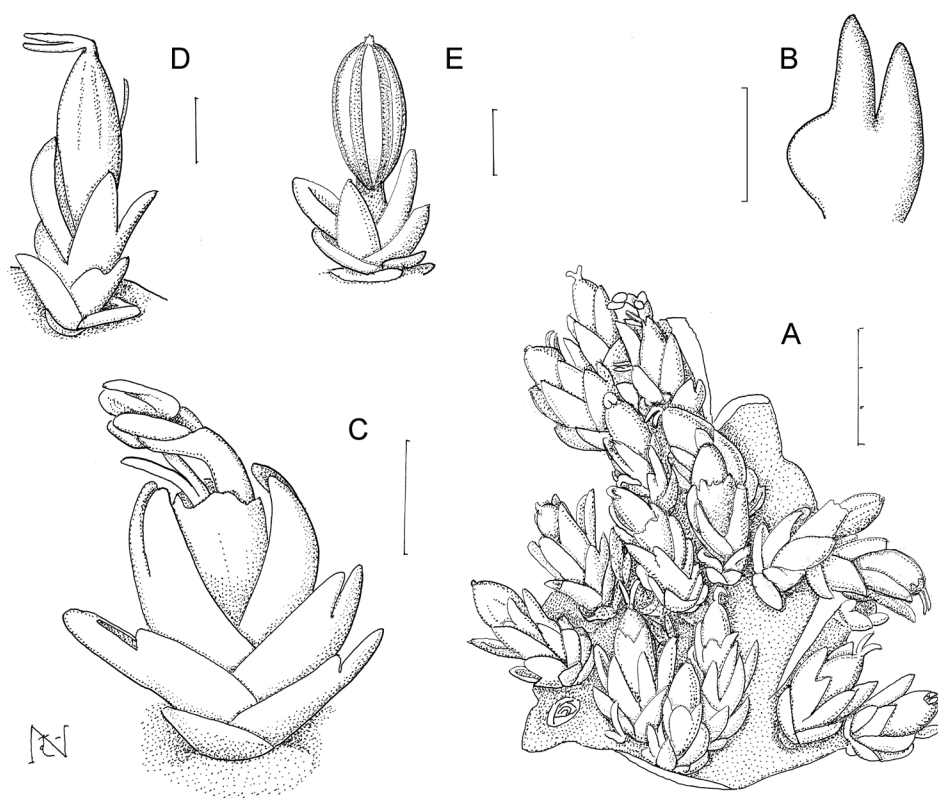


FIG. 1. *Thawatchaia laotica* (A–D, Koi *et al.* LK-307; E, Koi *et al.* LK-309). A. Flowers on dorsal surface of root. B. Bract. C. Young flower extruding from ruptured spathe subtended by bracts. D. Flower. E. Fruit. Scales bars = 3 mm in A, 1 mm in B–E.

middle and dorsal lobes, narrowly deltoid, apex bluntly acute, dorsal lobe subequal to middle lobe or slightly shorter, ventral lobe semicircular, much shorter than middle and dorsal lobes; lower bracts smaller than upper; spathe ellipsoid, 2–3.2 mm long, mucronate, mucrones ca. 0.3 mm long, ruptured irregularly near apex; pedicel ca. 0.2 mm long; tepals 2, one on each side of stamens, attached below middle of ovary stalk, 2–3.5 mm long, reaching above middle of ovary, linear; stamens 2, caducous, filaments forked 4/5–5/6 from base, 2.5–3 mm long; anthers ellipsoid, 0.5–0.8 mm long; stalk of ovary 0.5–0.8 mm long; ovary ellipsoid, 2–2.2 × 0.8–1 mm, 2-locular; stigmas 2, to 1.2–1.5 mm long, forked above base, equal, linear, entire, blunt or pointed; ovules 8–16 per locule, borne on whole septum surface except in lower central area; stalk of capsule 1.5–2 mm

long; capsule ellipsoid, slightly flattened, 2–2.2 × 0.9–1 mm, ribs 7–8, dehiscent by 2 equal valves.

Distribution. Northern Laos (Luang Namtha, Bokeo). Endemic to Laos.

Notes. *Thawatchaia laotica* differs from *T. trilobata* M. Kato, Koi & Y. Kita in the remarkably asymmetrical lobed bracts with middle and dorsal lobes narrowly deltoid, and ventral lobe semicircular (trilobed with all lobes subdeltoid and apically blunt in *T. trilobata*), filaments forked 4/5–5/6 from base (forked above middle), and stigmas 1.2–1.5 mm long (0.6–1 mm).

Thawatchaia had been recognized as a monotypic genus endemic to Thailand. *Thawatchaia laotica* is the second species endemic to Laos and geographically distributed at higher latitudes than *T. trilobata* of northern (Chiang Mai) and northeastern (Loei) Thailand. In Koi *et al.* (2012),

T. laotica was treated as conspecific with *T. trilobata*, but the two species are distinct morphologically and phylogenetically.

Specimens examined. Northern Laos. Luang Namtha Prov.: stream along Route 17B, Ban Kang Kao, 576 m alt., 20°59'49.9" N, 100°55'09.7" E, S. Koi, N. Katayama & T. Wongprasert LK-309 (TNS); Nam Tha river, Ban Sop-tout, 532 m alt., 20°54'30.6" N, 101°25'56.8" E, S. Koi, N. Katayama & T. Wongprasert LK-310 (TNS); Nam Tha river at bridge 24 km from Luang Namtha, near Ban Sop Shin, Nam Ha National Protected Area, 544 m alt., 20°53'03.4" N, 101°28'19.0" E, S. Koi, N. Katayama & T. Wongprasert LK-312 (TNS). —Bokeo Prov.: Houay Kalok stream, 474 m alt., 20°21'49.8" N, 100°41'48.4" E, S. Koi, N. Katayama & T. Wongprasert LK-319 (TNS).

Hydrobryum luangnamtaense Koi & M. Kato, **sp. nov.** —Fig. 2

Typus. Northern Laos. Luang Namtha Province: Nam Tha river, Ban Sin Oudon, 511 m, 20°49'16.7" N, 101°28'06.3" E, 15 Jan. 2011, S. Koi, N. Katayama & T. Wongprasert LK-316 (holotype TNS!, isotype HNL!).

Root crustose, adhering to rock by thin pads of rhizoids, irregularly lobed, raised in annual rings around tufts of leaves; leaves 1–4 per tuft, erect, needle-like, terete, 2–3.5 mm long. Flowering shoots appressed, flower solitary at apex; bracts uniform, in two rows, 3–6, ovate, 1–1.5 mm long, papillate; spathella papillate, irregularly ruptured near apex at anthesis; pedicel ca. 0.4 mm long; tepals 2, 1 on each side of stamen, linear, ca. 1.5 mm long; stamens 2, branched slightly more than 1/2 from base, 2.5–3.5 mm long, longer than pistil; stalk of ovary ca. 1 mm long; ovary 2-locular, ellipsoid, flattened, ca. $2 \times 1.3 \times 1$ mm; stigmas 2, narrowly deltoid, basal part flattened, facing each other, equal or subequal, 0.6–1 mm long, forked above base; ovules on whole septum except in lower central area, 20–43 per locule; stalk of capsule 0.5–1 mm long; capsule ellipsoid, flattened, ca. 2.5×1.2 – 1.5×0.9 –1 mm, dehiscing by 2 equal valves; ribs 16–17.

Distribution. Northern Laos (Luang Namtha). Endemic to Laos.

Notes. Phylogenetically, *Hydrobryum luangnamtaense* is sister to the clade of *H. loeicum* M.

Kato and *H. vientianense* (M. Kato & Fukuoka) Koi & M. Kato, and all three species are sister to *H. phetchabunense* M. Kato (Koi *et al.* 2012). In Koi *et al.*'s (2012) tree, specimens LK-313–LK-317 were named *Hydrobryum* sp. *Hydrobryum luangnamtaense* is similar to *H. loeicum* from northeastern Thailand and *H. vientianense* from north central Laos and northeastern Thailand, in the papillate bracts and spathellas, the stamens forked above middle and longer than the pistils, and the number of ribs on the capsule. It differs from the two species in the narrowly deltoid stigma (subulate in both species), the 20–43 ovules borne over the whole ovary septum except in the lower central part (4–8 in *H. loeicum*; 8–28 in *H. vientianense*) and the short stalk of the capsule (1–2 mm; 1–2.5 mm). Also it differs from *H. phetchabunense*, with a less close affinity, by the number of ovules (5–8 in *H. phetchabunense*) and the short stalk of capsule (1–1.5 mm).

Specimens examined. Northern Laos. Luang Namtha Province: Nam Tha river at bridge 24 km from Luang Namtha, near Ban Sop Shin, Nam Ha National Protected Area, 544 m alt., 20°53'03.4" N, 101°28'19.0" E, S. Koi, N. Katayama & T. Wongprasert LK-313 (TNS); ditto, S. Koi, N. Katayama & T. Wongprasert LK-314 (TNS); ditto, S. Koi, N. Katayama & T. Wongprasert LK-315 (TNS); Nam Tha river, Ban Sin Oudon, 511 m, 20°49'16.7" N, 101°28'06.3" E, S. Koi, N. Katayama & T. Wongprasert LK-317 (TNS).

Hydrobryum japonicum Imamura, Bot. Mag. Tokyo 42: 376. 1928; Cusset, Bull. Mus. Natl. Hist. Nat. Paris, B, Adansonia 14(1): 46. 1992, p.p.; Kato, Acta Phytotax. Geobot. 55: 157. 2004.

Distribution. Northern Laos (Bokeo, Luang Namtha, Oudom Xai), new to Laos; southwestern Japan, South Central China (Yunnan), northern Vietnam, Thailand (Northern, Northeastern, Southwestern), and northern Myanmar.

Notes. The Lao specimens below have 2–5 smooth-surfaced ovate bracts, smooth-surfaced spathella, two stamens with a common andropod, about 2 times as long (3–4 mm) as the ovary (1.3–2.5 mm), 2-locular, flattened ellipsoid or ovoid ovary with 10–21 ovules on the marginal surface

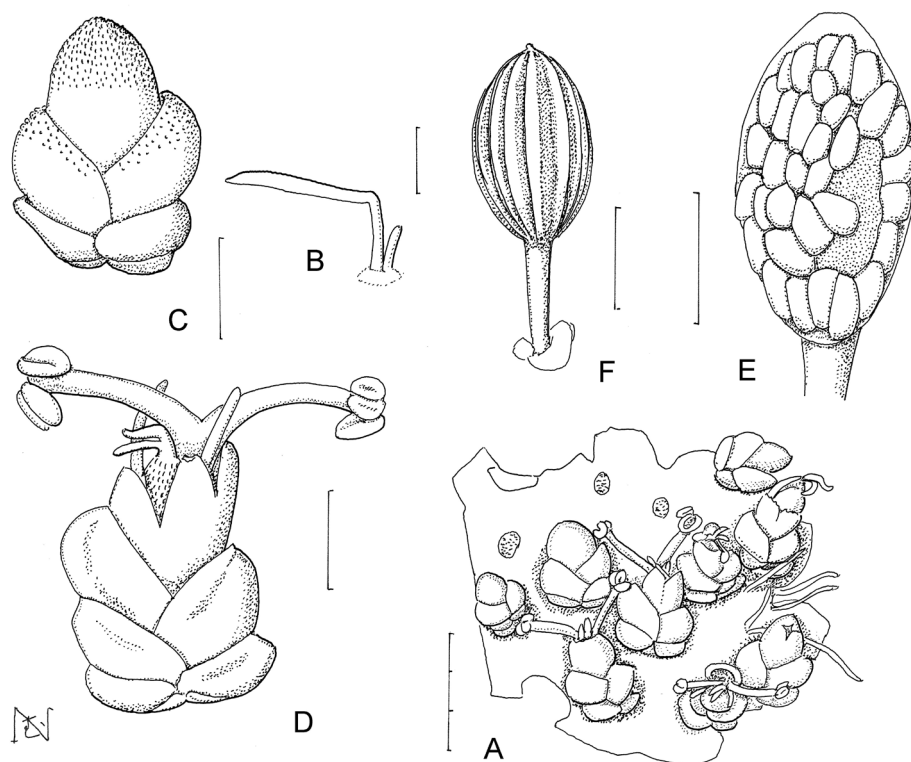


FIG. 2. *Hydrobryum luangnamtaense* (A–E, Koi et al. LK-316; F, Koi et al. LK-313). A. Flowers on dorsal surface of root. B. Leaves. C. Flower bud enclosed by spathe and subtended by bracts. D. Flower extruding from ruptured spathe subtended by bracts. E. Ovules on septum with sterile central part. F. Fruit. Scales bars = 3 mm in A, 1 mm in B–E.

of the septum, 2 equal, subulate stigmas, and 10–14(–16) ribs on the capsule. The ovules in Thai and Japanese plants are slightly fewer (10–15) (Nakayama & Minamitani 1999, Werukamkul et al. 2012).

Hydrobryum japonicum is the most widely distributed species of *Hydrobryum* in eastern and southeastern Asia (Kato 2013). All Lao specimens except LK-301 have the same *matK* haplotype as one specimen from Japan and 15 specimens from northern and southwestern Thailand. This haplotype is most widely distributed among about 10 haplotypes of *Hydrobryum japonicum* (Koi et al. 2012, S. Koi, unpubl. data).

Specimens examined. Northern Laos. Luang Namtha Prov.: Nam Lueang stream, along Route 17A, 43 km from Muang Sing, 600 m alt., 21°05'09.4" N, 101°22'26.8" E, S.

Koi, N. Katayama & T. Wongprasert LK-302 (TNS); Nam Lueang stream, along Route 17A, Ban Bone Xay, 644 m alt., 21°05'35.3" N, 101°21'34.2" E, S. Koi, N. Katayama & T. Wongprasert LK-303 (TNS); stream at entrance of Phagneung Phoukulom waterfall, along Route 17A, 17 km from Muang Sing, Nam Ha National Protected Area, 884 m alt., 21°07'12.0" N, 101°14'37.9" E, S. Koi, N. Katayama & T. Wongprasert LK-304 (TNS); stream under bridge on Route 17A, at the border of Nam Ha National Protected Area, 765 m alt., 21°08'09.7" N, 101°12'00.2" E, S. Koi, N. Katayama & T. Wongprasert LK-305 (TNS); stream along Route 17B, 17 km from Muang Sing, 723 m alt., 21°04'57.5" N, 101°03'35.5" E, S. Koi, N. Katayama & T. Wongprasert LK-306 (TNS); stream along Route 17B, Ban Kang Kao, 576 m alt., 20°59'49.9" N, 100°55'09.7" E, S. Koi, N. Katayama & T. Wongprasert LK-308 (TNS). —Bokeo Prov.: stream in Ban Ta Pha, 558 m alt., 20°25'47.5" N, 100°53'06.1" E, S. Koi, N. Katayama & T. Wongprasert LK-318 (TNS). —Oudom Xai Prov.: Nam Kad waterfall, Ban Faen, 713 m alt., 20°42'40.3" N, 102°06'07.9" E, S. Koi, N. Katayama & T. Wongprasert LK-301 (TNS).

Polypleurum longistylusum M. Kato, Acta Phytotax. Geobot. 57: 40, f. 16. 2006.

Distribution. Southern Laos (Attapeu), new to Laos; Thailand (Eastern). The Lao plants occur sympatrically with *Dalzellia* sp. and *Cladopus pierrei*.

Notes. The plant of *Polypleurum longistylusum*, although fragmentary, has the diagnostic characters cited below of *Polypleurum longistylusum*, such as the flowering shoots borne on the flanks between successive root branches, the papillate spathella nearly completely enclosing the mature ovary and the lower part of filament, the single stamen, the 1-locular ovary, the stigmas forked at or above middle, the ovules borne on the marginal surface of the septum, and ca. 12 ribs on the capsule. Molecular data support the identification (Koi *et al.* 2012, S. Koi, unpubl. data).

Specimen examined. Southern Laos. Attapeu Prov.: Tad Xay Pha waterfall, Se Pian National Park, 106°26'20.7" E, 14°46' 34.3" N, 137 m alt., M. Kato, S. Koi & T. Wongprasert LK-427 (TNS).

Paracladopus chanthaburiensis Koi & M. Kato; Koi *et al.* Taxon 57: 203. 2008.

Distribution. Southern Laos (Attapeu), new to Laos; Thailand (Southeastern).

Notes. *Paracladopus* is a bispecific genus. Molecular data (S. Koi unpubl. data) show that the specimen below is assigned to *Paracladopus chanthaburiensis*. The specimen is incomplete consisting of transitional plants between the sterile and fertile stages; the vegetative leaves are en-

siform with rudimentary lobes at the base, and the bracts are digitate, often with elongate lobes similar to vegetative leaves. This species shares with *P. Chiangmaiensis* M. Kato the tufts of leaves and flowering shoots borne on the flank of the root between root branches (the flower characters are unknown). *Paracladopus chanthaburiensis* differs from *P. Chiangmaiensis* in the digitate bracts (vs. linear with basal lobes in *P. Chiangmaiensis*).

Specimen examined. Southern Laos. Attapeu: Se Lamong stream, Dong Ampham National Protected Area, 107°16'6.3" E, 14°44' 40.9" N, 178 m alt., M. Kato, S. Koi & T. Wongprasert LK-434 (TNS).

Notes on Podostemaceae in Laos

The present and previous papers show that Laos harbors 20 species and six genera of Podostemoideae, and 15 species and three genera of Tristichioideae (Koi & Kato 2012, 2015). Eight of the nine genera are shared with Thailand, and the monotypic genus *Hydrodiscus* (Podostemoideae) is endemic to Laos. Ten of the 20 species of Podostemoideae, including *Hydrobryum luangnamtaense* and *Thawatchaia laotica*, are endemic to Laos; seven species including *Polypleurum longistylusum* and *Paracladopus chanthaburiensis* are also in Thailand; one also in Vietnam (also Thailand; P. Werukamlul *et al.* unpubl. data); one also in Thailand, Cambodia and northern India; and one, *H. japonicum*, is widely distributed from northern Myanmar to Japan. In Tristichioideae, seven species are endemic to Laos, six species are

Key to the genera of Podostemoideae in Laos

- 1a. Root absent; shoots elongate, floating, anchoring with disk-like base *Hydrodiscus*
- 1b. Roots present; shoots apparently absent or reduced, borne on root 2
- 2a. Bracts simple 3
- 2b. Bracts lobed or digitate 4
- 3a. Roots ribbon-like with tufts of leaves or flowering shoots on flanks or at sinuses of root branches; valves of capsule unequal or subequal *Polypleurum*
- 3b. Roots subcylindrical or ribbon-like with tufts of leaves or flowering shoots at sinuses of root branches, or roots crustose; valves of capsule equal *Hydrobryum*
- 4a. Roots crustose; capsules ellipsoid, flattened *Thawatchaia*
- 4b. Roots ribbon-like; capsules globose 5
- 5a. Tufts of leaves or flowering shoots on flanks of root; capsules ribbed *Paracladopus*
- 5b. Tufts of leaves or flowering shoots at sinuses of root branches; capsules smooth *Cladopus*

Key to the species of Podostemoideae in Laos

- 1a. Root absent; shoots to 1 m long, branched, floating, anchoring with disk-like base *Hydrodiscus koyamae*
- 1b. Roots present; shoots apparently absent or reduced, rarely (in *H. takakioides*) flowering shoots to 1.5 cm long, borne on root 2
- 2a. Roots cylindrical to ribbon-like 3
- 2b. Roots crustose 12
- 3a. Roots floating at least distally 4
- 3b. Roots adhering to rock along entire length 5
- 4a. Roots adhering by disk-like base; tufts of leaves (shoots) and flowers borne at sinuses of root branches *Hydrobryum ramosum*
- 4b. Roots adhering by proximal parts; tufts of leaves and flowers borne on flank of root between successive branches *Polypleurum wallichii*
- 5a. Tufts of leaves and flowers borne on flank of root between successive branches 6
- 5b. Tufts of leaves and flowers borne only at sinuses of root branches 9
- 6a. Bracts trilobed or digitate, capsules globose 7
- 6b. Bracts simple; capsules ellipsoid 8
- 7a. Bracts trilobed with reduced lateral lobes *Paracladopus chiangmaiensis*
- 7b. Bracts digitate *Paracladopus chanthaburiensis*
- 8a. Stamens 2–3 mm long; ovary 2-locular, ca. 1 mm long; stigmas forked at base; ribs of capsules 8 or 9 *Polypleurum schmidtianum*
- 8b. Stamens up to 1.5 mm long; ovary 1-locular, 1.2–2 mm long; stigmas forked at or above middle; ribs of capsules ca. 12 *Polypleurum longistylusum*
- 9a. Bracts digitate; capsules globose or ellipsoid, smooth *Cladopus pierrei*
- 9b. Bracts entire; capsules ellipsoid, ribbed 10
- 10a. Flowering shoots erect; capsules not flattened *Polypleurum pluricostatum*
- 10b. Flowering shoots appressed; capsules flattened 11
- 11a. Roots to 1 mm wide; stamen 1 *Hydrobryum subcylindricum*
- 11b. Roots 1–2 mm wide; stamens 2 *Hydrobryum taeniatum*
- 12a. Bracts trilobed *Thawatchaia laotica*
- 12b. Bracts simple 13
- 13a. Flowering shoots erect, 7–14 mm long; bracts terete, subulate *Hydrobryum takakioides*
- 13b. Flowering shoots appressed, less than 1.5 mm long; bracts flat, ovate at least at base 14
- 14a. Stamen 1; ovary 1-locular *Hydrobryum austrolaoticum*
- 14b. Stamens 2; ovary 1 or 2-locular 15
- 15a. Ovary 1-locular, subsessile, stalk 0.1–0.5 mm long, enclosed by spathe at maturity *Hydrobryum subcrustaceum*
- 15b. Ovary 2-locular, stalk 0.3–2 mm long, at least partly protruding from spathe 16
- 16a. Bracts distally acute to linear; basal part of ovary enclosed by spathe *Hydrobryum tardhuangense*
- 16b. Bracts ovate, obtuse; ovary exposed 17
- 17a. Bracts smooth *Hydrobryum japonicum*
- 17b. Bracts papillate 18
- 18a. Roots adhering to rock by prominent warty projections (holdfasts); stamens forked 1/4–1/8 from top *Hydrobryum verrucosum*
- 18b. Roots adhering by thin pads of rhizoids; stamens forked ca. 1/2–1/5 from apex 19
- 19a. Stigma subulate; stalk of capsule 1–2.5 mm long; ovules 8–27 per locule *Hydrobryum vientianense*
- 19b. Stigma narrowly deltoid; stalk of capsule 0.5–1 mm long; ovules 20–43 per locule *Hydrobryum luangnamtaense*

distributed also in Thailand, one is also in Thailand and Vietnam, and one is also in Cambodia (Koi & Kato 2015). Thus, Lao Podostemaceae are characterized by a number of endemic species (17 of 35 species, 49%) and most (13 species) of the rest common to only Thailand. Among the endemic species, *H. luangnamtaense*, *H. ramosum* (C. Cusset) Koi & M. Kato, and *H. takakioides* Koi & M. Kato are restricted to single rivers, while the others occur in multiple localities. Laos and Thailand together comprise a biodiversity hotspot for Podostemaceae, which is more diverse than southern Asia, the other hotspot in Asia (Willis 1902, Mathew & Satheesh 1997, Kato 2009).

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